Reinforced Masonry

Structural Engineers Association of Alaska

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About the Speaker

- Professional Engineer licensed in NY, OH, PA, WI
- Graduate of Rensselaer Polytechnic Institute
- Practicing for almost 21 years
- Principal at Ryan Biggs | Clark Davis (RBCD) structural engineering consulting firm with almost 50 employees and 50 years in business
- RBCD has extensive experience with masonry design, restoration and repair, and historic preservation
- Most importantly….Greg Latreille’s big brother☺

Overview

- Benefits of reinforced masonry construction
- Potential Challenges
- Applicable codes
- General design requirements for walls
- Tips for successful construction of reinforced masonry
- Considerations for connection of walls to floor and roof diaphragms
- Tips for construction of walls with openings
- Best practices for location of control joints
- Considerations for cavity wall construction and single wythe masonry

BENEFITS OF REINFORCED MASONRY

- Durable
- Fire Resistant
- Energy Efficient
- Cost Efficient
- Structurally Efficient

Potential Challenges

- Open floor plans
- Large open facades
- Field QA/QC
- Weather/Location
- Local workforce
- Site conditions
- Deflection limits
- Complex geometry

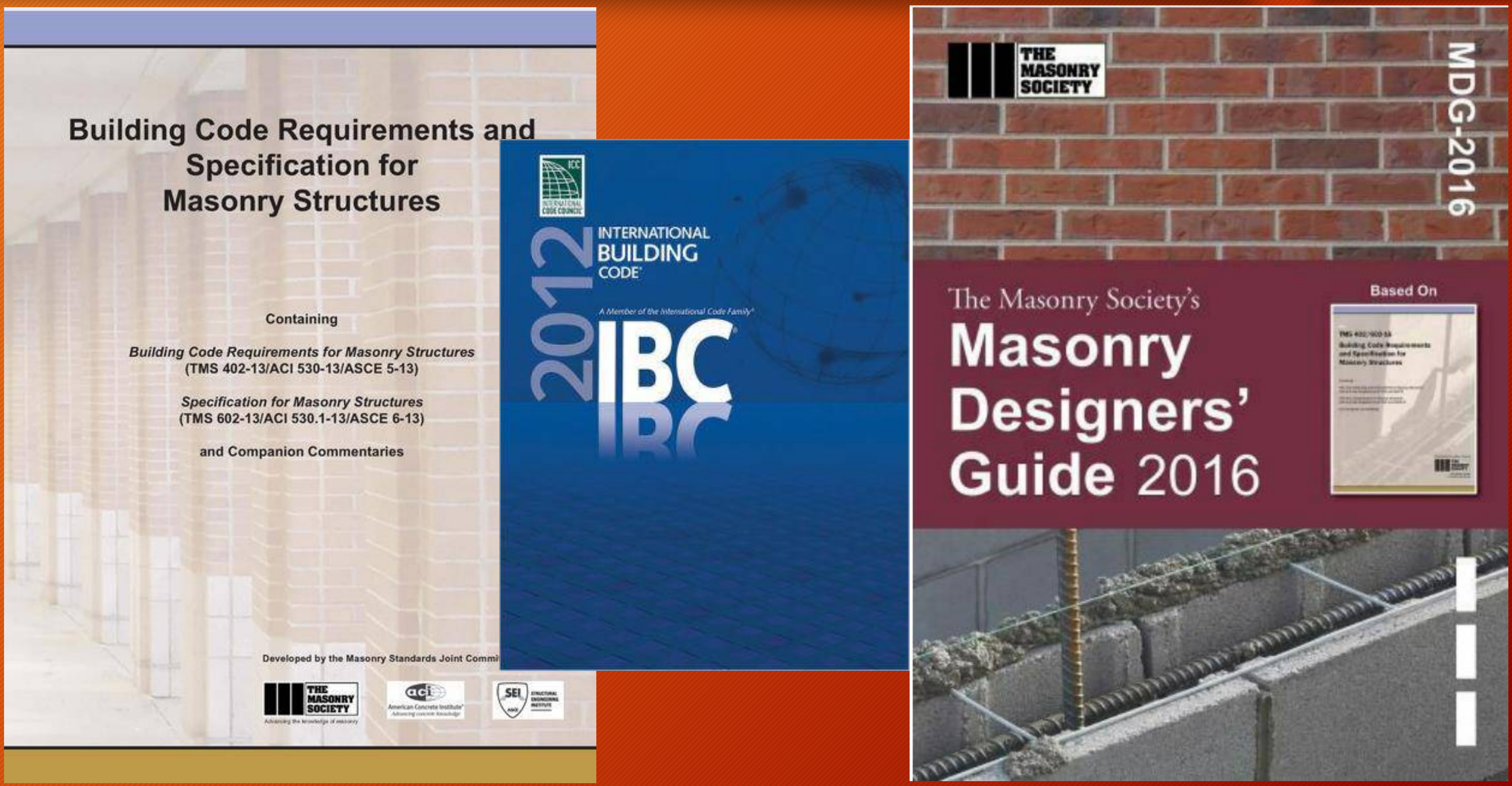
Engineer’s Role

- Understand code provisions
- Recognize common pitfalls during construction and design for them
- Develop a strong QA/QC plan
- Reach out to local masons
- Become a masonry apprentice
- Focus on constructible designs as they are key to a successful masonry project

Common Project Types

- K-12 schools
- Bus garages
- Corrections facilities
- Housing projects
- Higher education facilities

CODES – IBC 2012 – TMS 402/602-11



DESIGN METHODOLOGIES ASD or Strength??

Not major differences between the two and they are getting closer. Eamples:

- ASD Fs = 32,000 psi instead of 24,000 psi (previous)
- ASD Fm = 0.45f'm instead of 0.33f'm (previous)

Masonry research is generally Strength-based and will continue to be

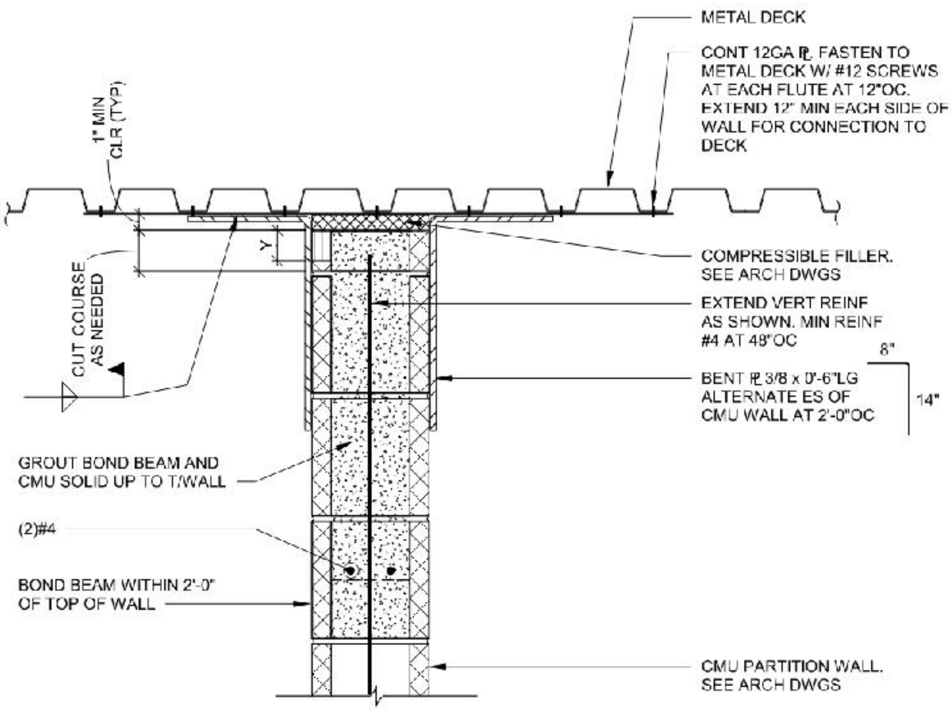
Consider learning and using Strength design

Walls!!!

General

- Bearing walls are generally more efficient than non-bearing walls
- Tops of walls need to be braced including interior partitions
- Pay attention to detailing for shear. If walls are not intended to be shear walls, they:
  - Should not be connected to floor and roof diaphragms for in-plane loads
  - Should not be built tight to building columns

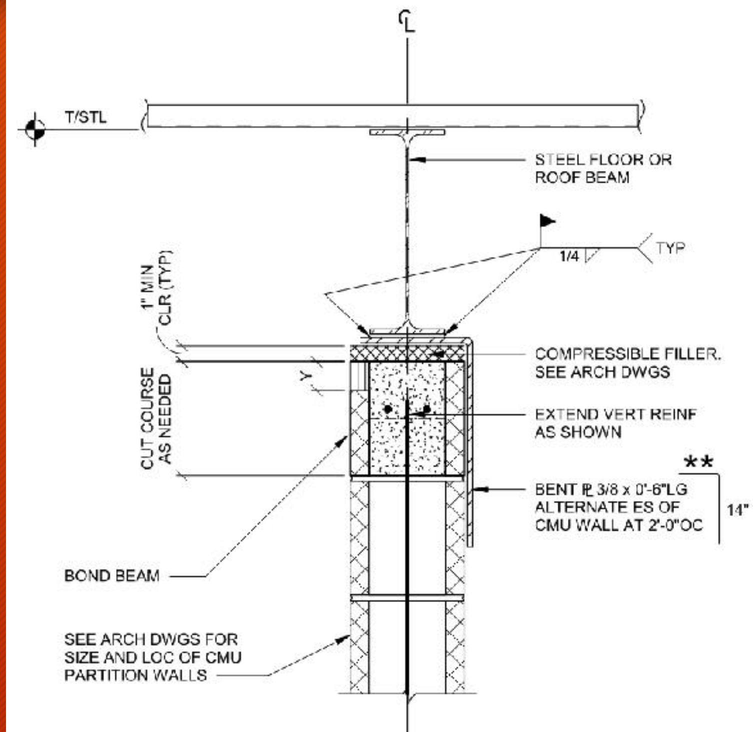
Non-Shear Wall



1 S4.02 **DETAIL AT TOP OF CMU PARTITION WALL**

NOT TO SCALE

NOTE:
Y (SHADED ▥) INDICATES NOTCH FACE SHELL (4" MAXIMUM) AS REQUIRED FOR GROUTING. FILL SOLID WITH MORTAR ABOVE GROUT TO TOP OF CMU.



2 S4.02 **DETAIL AT TOP OF CMU PARTITION WALL**

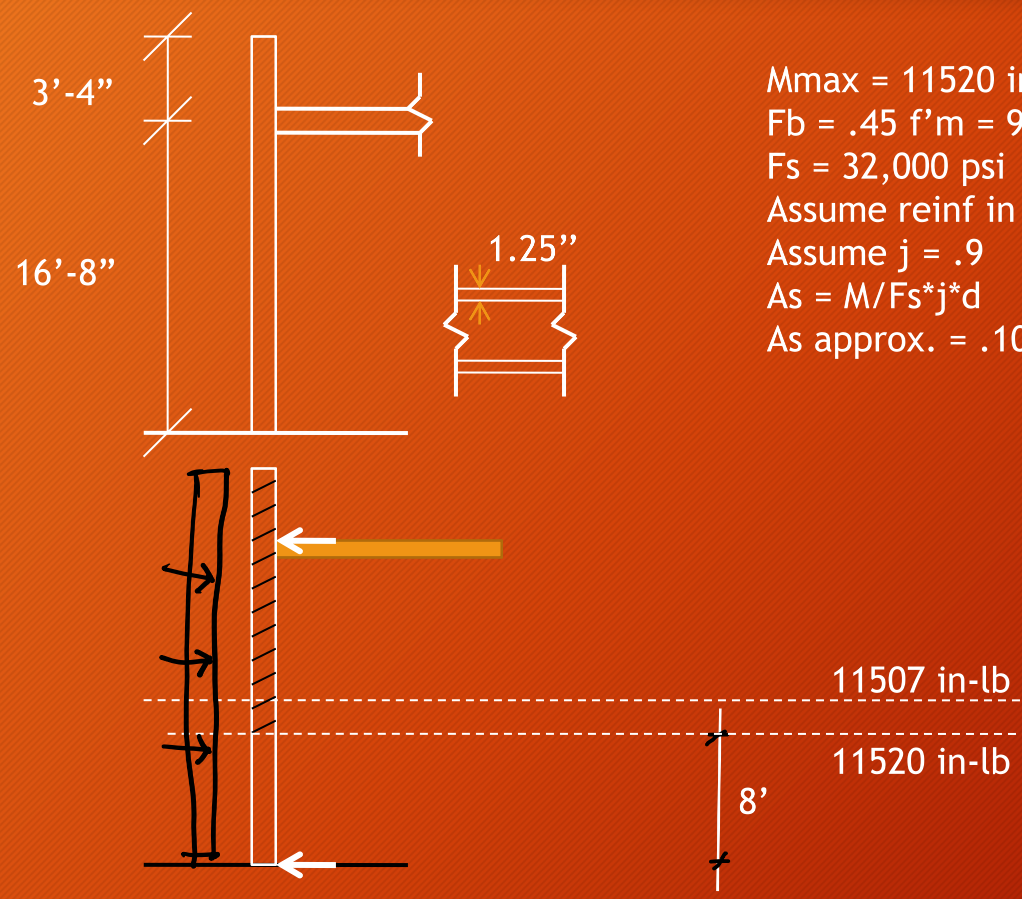
NOT TO SCALE

NOTES:
1. ** - INDICATES FLANGE WIDTH PLUS 2" OR WALL WIDTH PLUS 1/2" (WHICHEVER IS GREATER). COORDINATE WITH ARCHITECTURAL DRAWINGS.
2. Y (SHADED ▥) INDICATES NOTCH FACE SHELL (4" MAXIMUM) AS REQUIRED FOR GROUTING. FILL SOLID WITH MORTAR ABOVE GROUT TO TOP OF CMU.

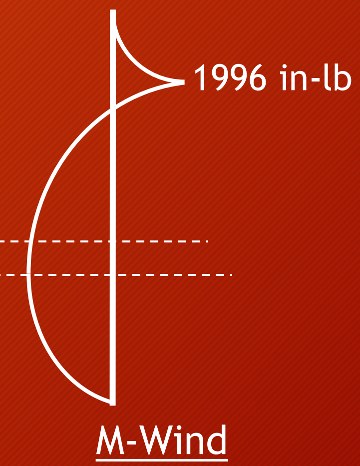
Out-of-Plane Loads Allowable Stress

- Wind: 30psf
- Unit Strength: 2000 psi
- f'm= 2000 psi
- 8" cmu DL- ungrouted, 33psf

Example – Reinforced Non-Bearing Wall



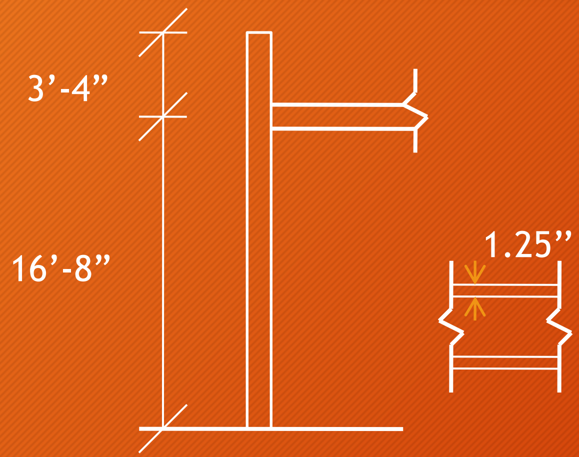
Mmax = 11520 in-lb
Fb = .45 f'm = 900 psi
Fs = 32,000 psi
Assume reinf in center of cell d = 3.75"
Assume j = .9
As = M/Fs*j*d
As approx. = .107 in^2



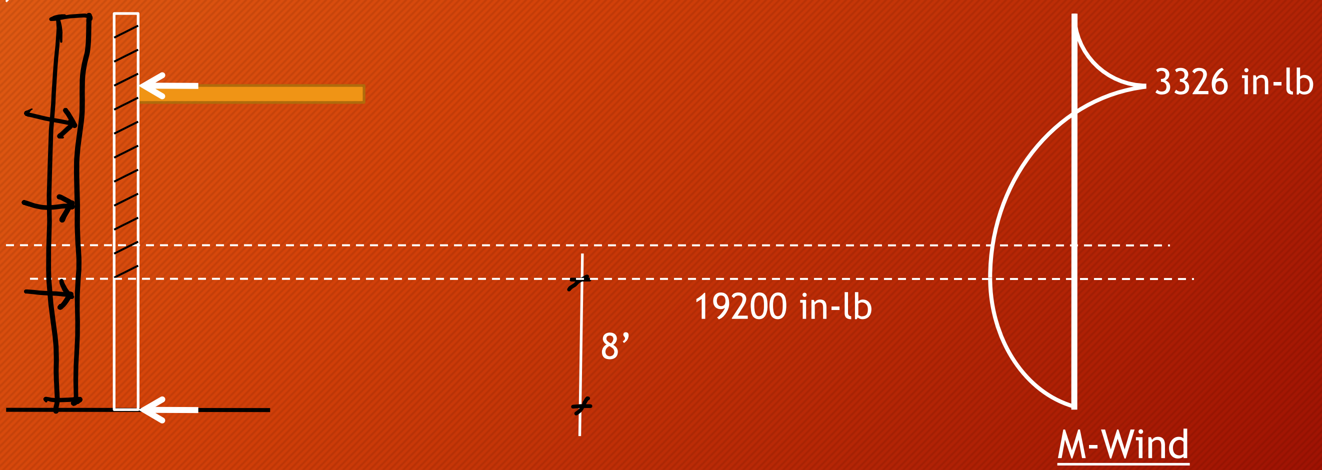
Out-of-Plane Loads Strength Design

- Wind: 50psf (Factored)
- Unit Strength: 2000 psi
- f'm= 2000 psi
- 8" cmu DL- ungrouted, 33psf

Example – Reinforced Non-Bearing Wall



Mu (max) = 19200 In-lb/ft of wall
fy = 60,000 psi
Assume reinf in center of cell d = 3.75"
Φ= 0.9
b = 12" (per foot basis)
a = d - SQRT [d^2 – (2Mu/0.8*Φ*f'm*b)]
As = (0.8*f'm*b*a)/fy
As approx. = 0.097 in^2/ft

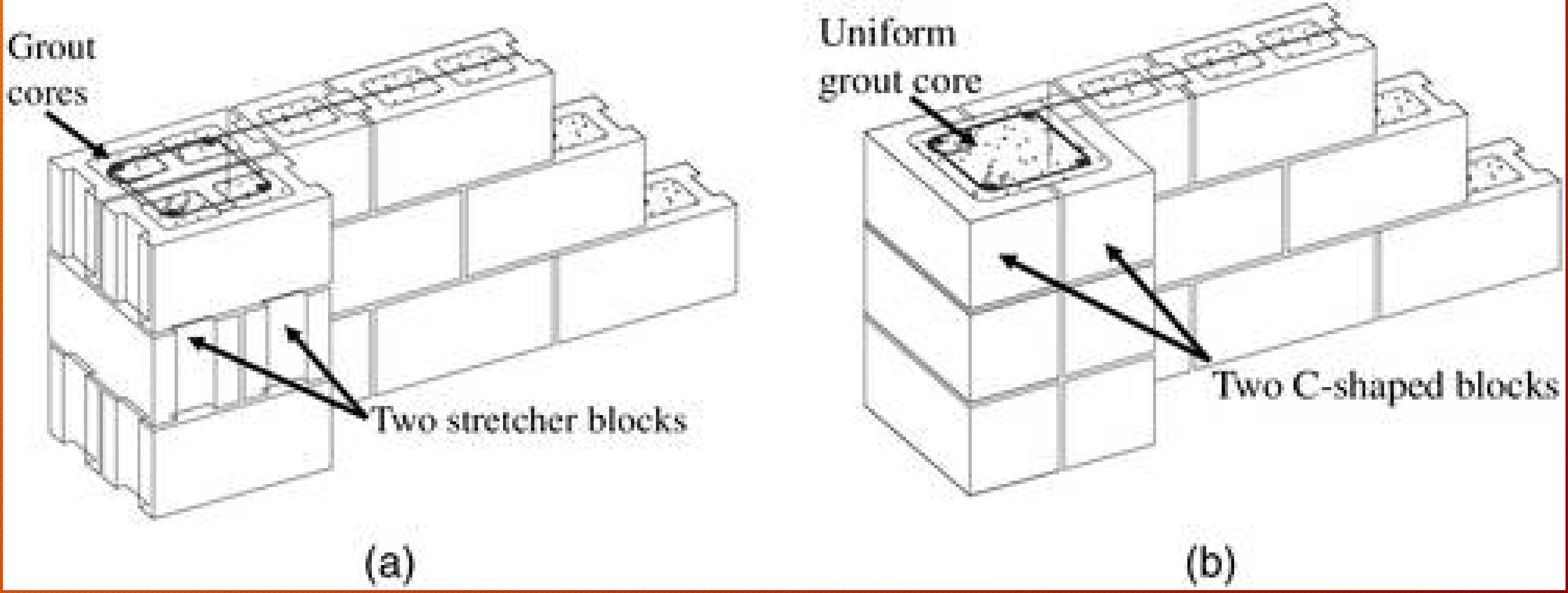


Walls with Openings

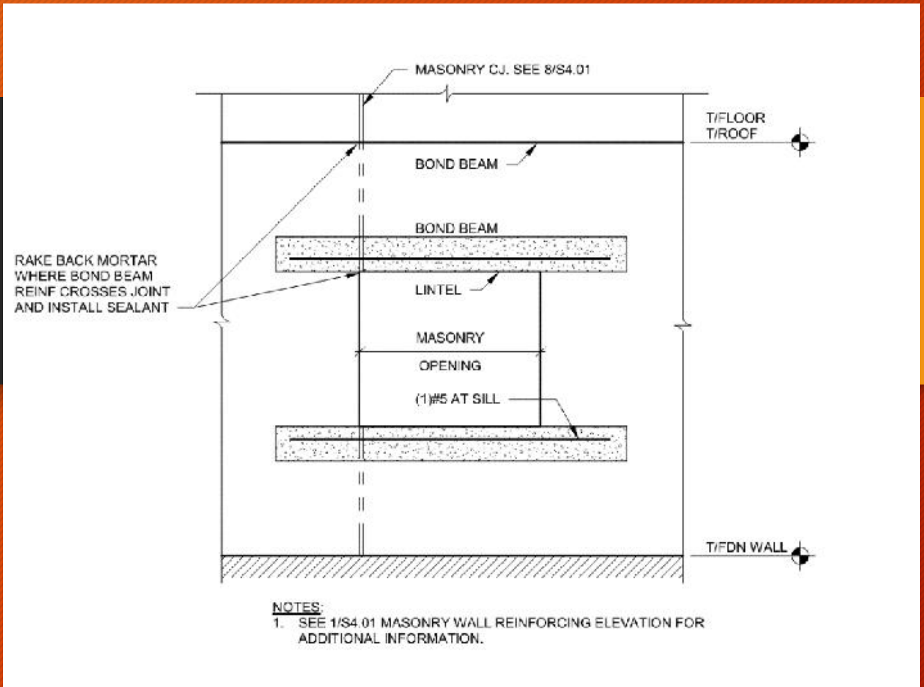
- Consider location of control joints in design of vertical reinforcement at jambs.
- Plan ahead for lintels.
- Discuss layout with Architect early in the project. BE MODULAR!!
- Don't be left with too little masonry to satisfy design and constructability

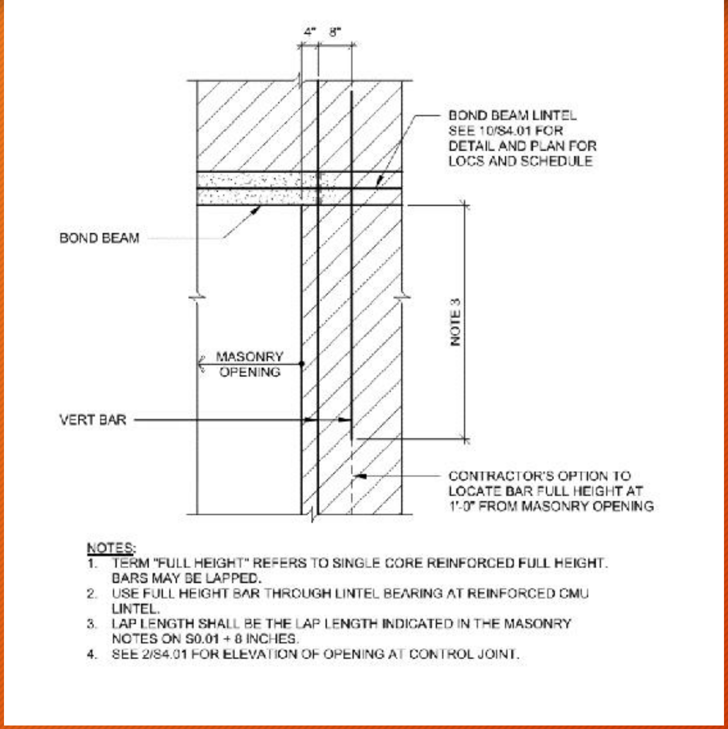
Big Openings and Tall Walls

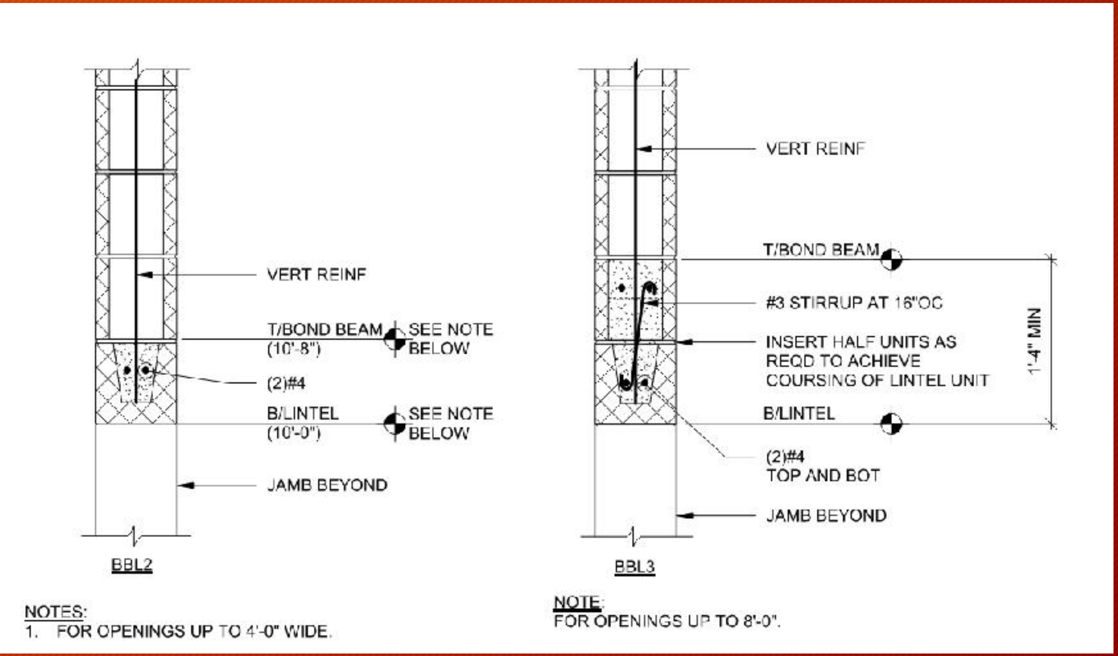
- Larger CMU – 8” standard, but 10”-12”-16” are available
- Consider pilasters



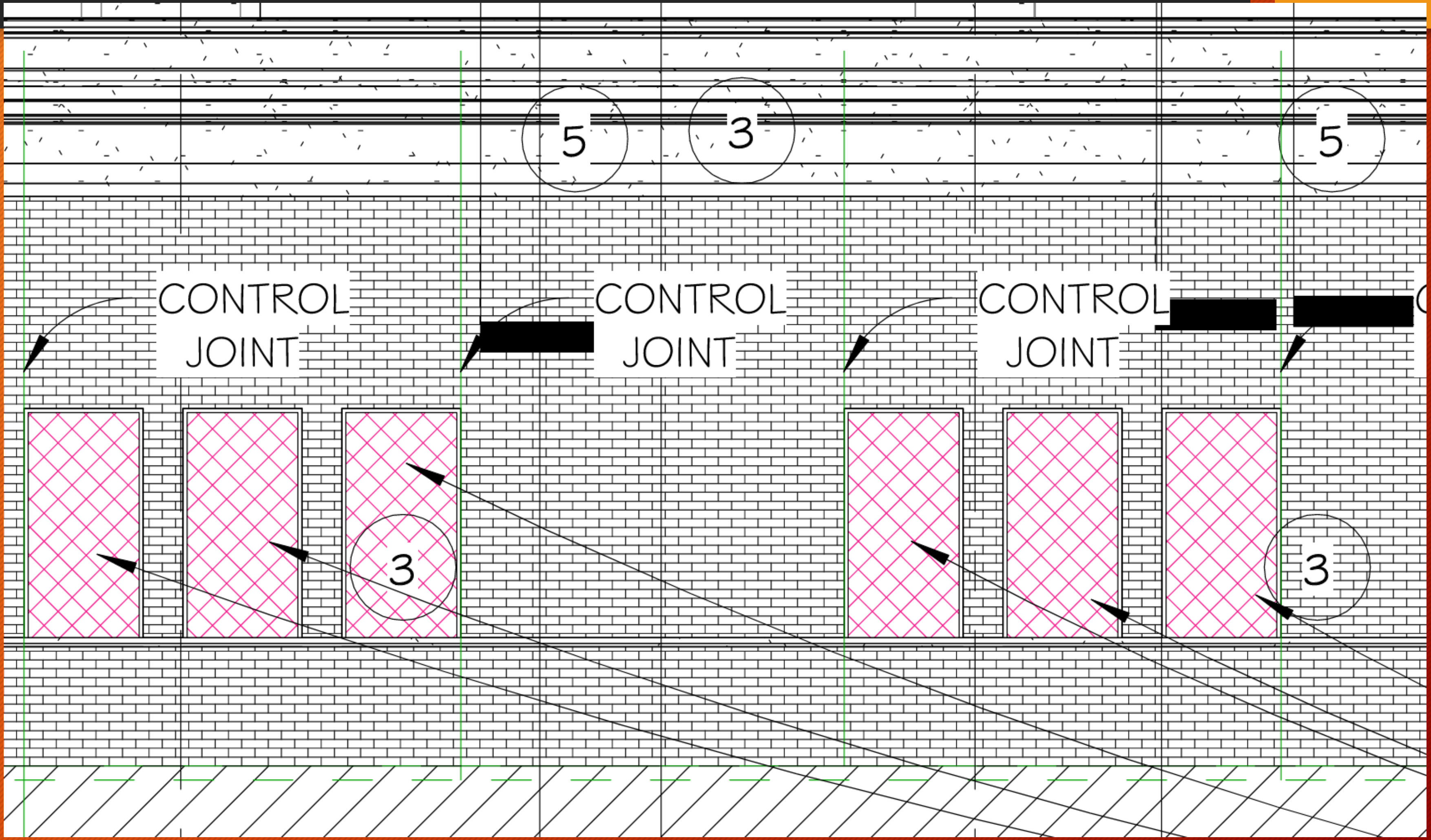
Lintels


MASONRY CJ. SEE 8/S4.01
T/FLOOR
T/ROOF
BOND BEAM
BOND BEAM
RAKE BACK MORTAR
WHERE BOND BEAM
REINF CROSSES JOINT
AND INSTALL SEALANT
LINTEL
MASONRY
OPENING
(1)#5 AT SILL
T/FDN WALL
NOTES:
1. SEE 1/S4.01 MASONRY WALL REINFORCING ELEVATION FOR ADDITIONAL INFORMATION.


4"
8"
BOND BEAM LINTEL
SEE 10/S4.01 FOR
DETAIL AND PLAN FOR
LOCS AND SCHEDULE
BOND BEAM
NOTE 3
MASONRY
OPENING
VERT BAR
CONTRACTOR'S OPTION TO
LOCATE BAR FULL HEIGHT AT
1'-0" FROM MASONRY OPENING
NOTES:
1. TERM "FULL HEIGHT" REFERS TO SINGLE CORE REINFORCED FULL HEIGHT. BARS MAY BE LAPPED.
2. USE FULL HEIGHT BAR THROUGH LINTEL BEARING AT REINFORCED CMU LINTEL.
3. LAP LENGTH SHALL BE THE LAP LENGTH INDICATED IN THE MASONRY NOTES ON S0.01 + 8 INCHES.
4. SEE 2/S4.01 FOR ELEVATION OF OPENING AT CONTROL JOINT.

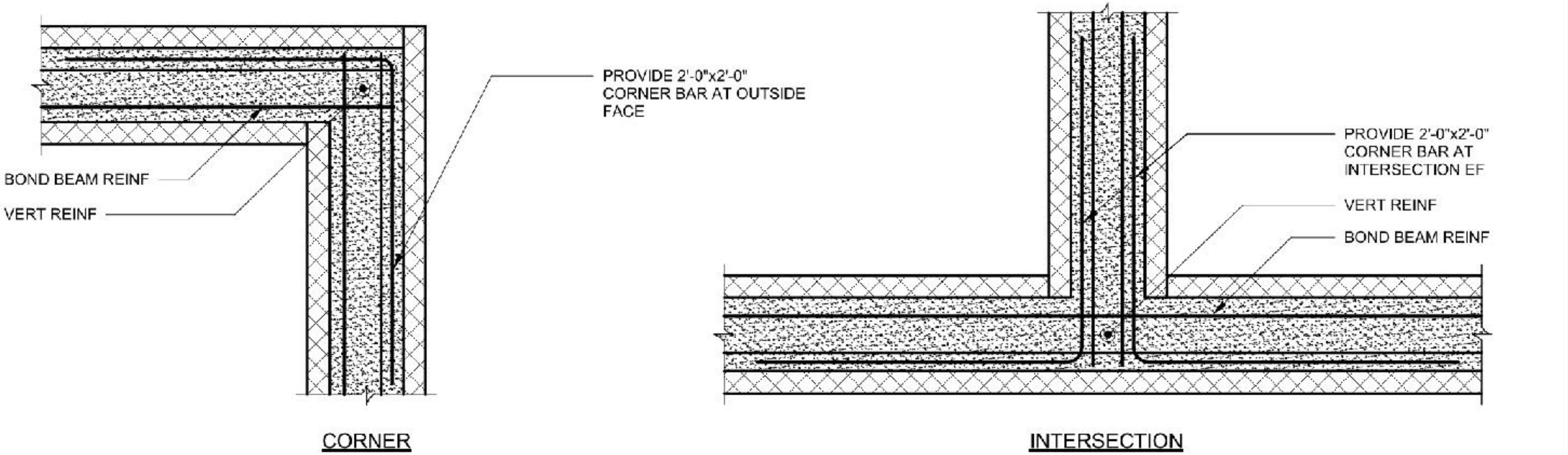

VERT REINF
T/BOND BEAM
(10'-8")
SEE NOTE
BELOW
(2)#4
B/LINTEL
(10'-0")
SEE NOTE
BELOW
JAMB BEYOND
BBL2
NOTES:
1. FOR OPENINGS UP TO 4'-0" WIDE.
VERT REINF
T/BOND BEAM
#3 STIRRUP AT 16"OC
INSERT HALF UNITS AS
REQD TO ACHIEVE
COURSING OF LINTEL UNIT
1'-4" MIN
B/LINTEL
(2)#4
TOP AND BOT
JAMB BEYOND
BBL3
NOTE:
FOR OPENINGS UP TO 8'-0".

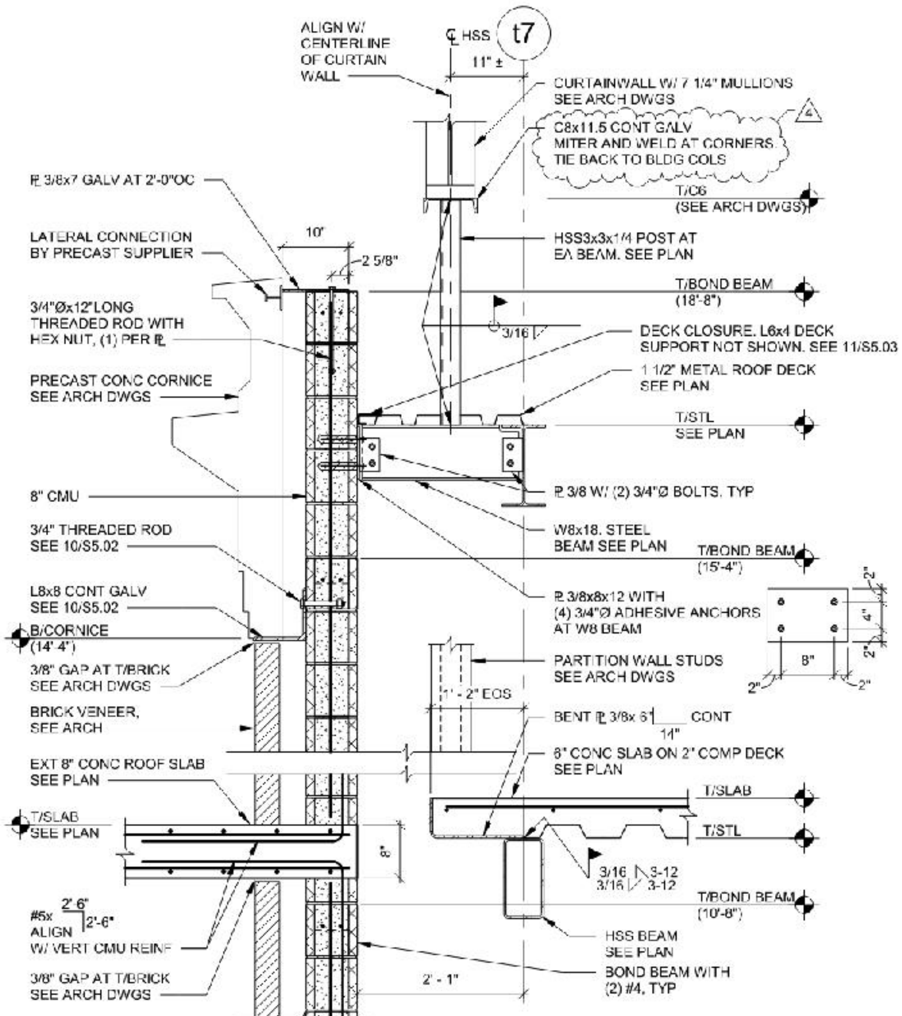
Lintels

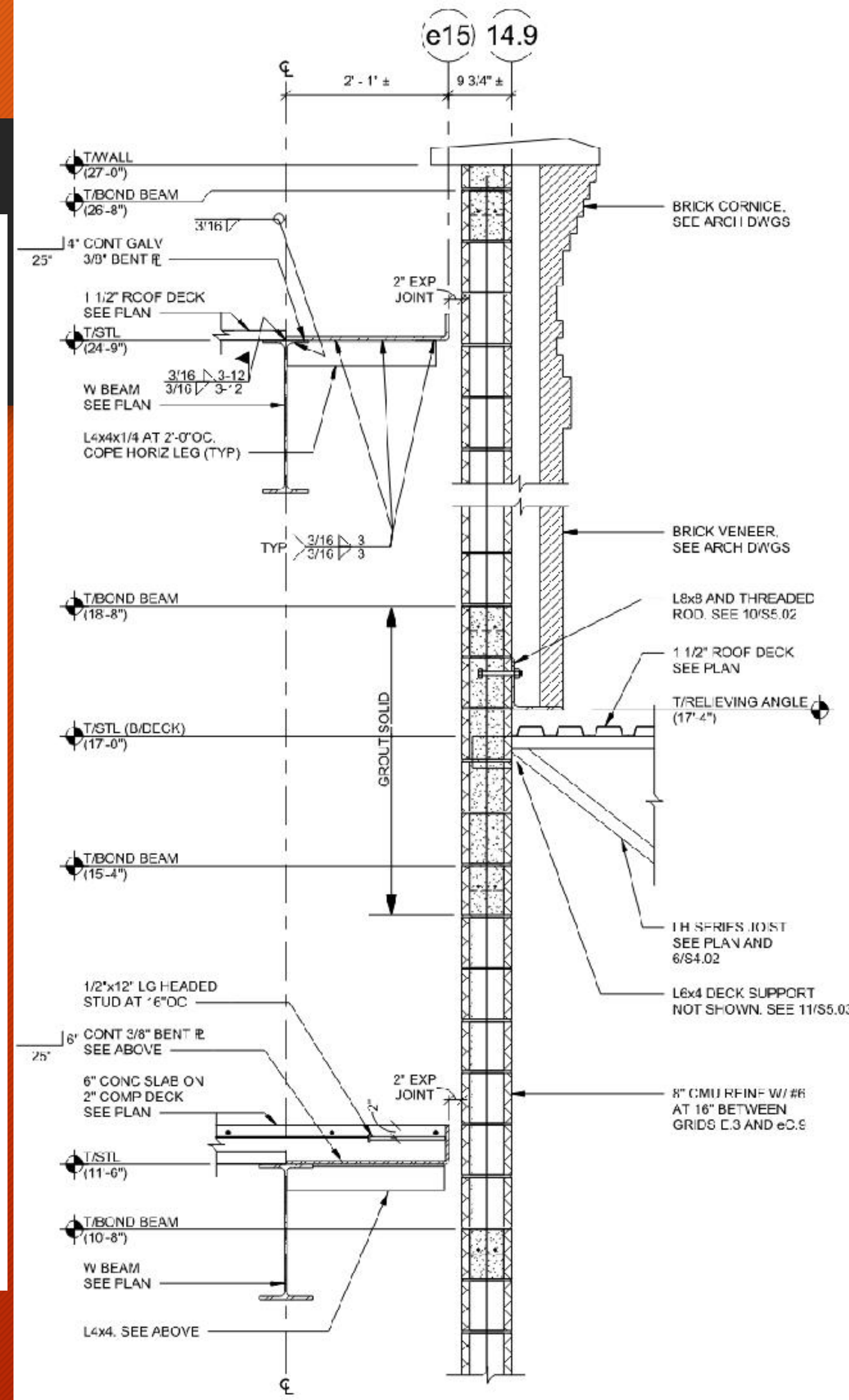

5
3
5
CONTROL JOINT
[redacted]
CONTROL JOINT
CONTROL JOINT
[redacted]
3
3

Bond Beams

BOND BEAM ELEVATION SCHEDULE	
LOCATION	T/BOND BEAM ELEVATION
SOUTH ADDITION	9'-4", 12'-8", 17'-4", 22'-8", 26'-8"
EAST ADDITION	10'-8", 15'-4", 18'-8"







EXIBLE CLOSURES AT

Bearing Walls

- More efficient use of reinforced masonry than non-load bearing
- Running bond layout is most common
- Architects will sometimes specify stack bond for exposed masonry
- Note load distribution for point loads on stack bond walls

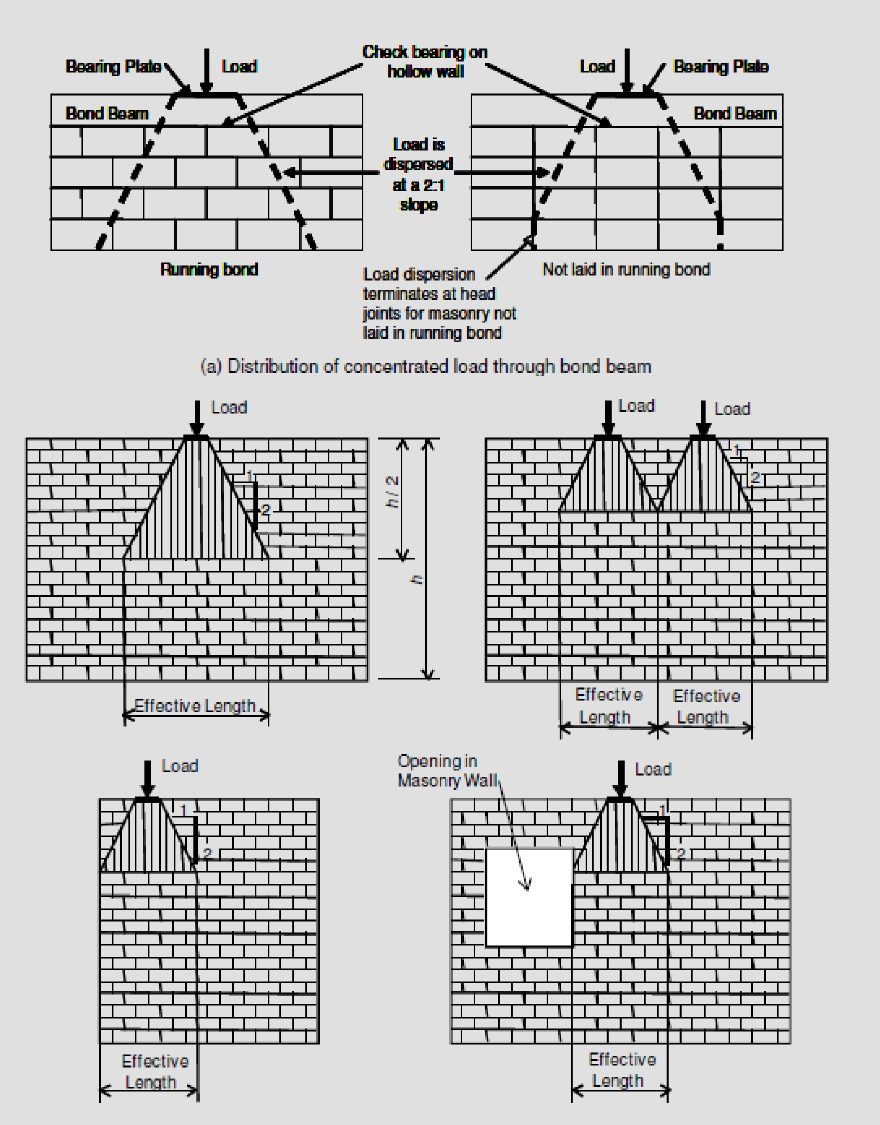
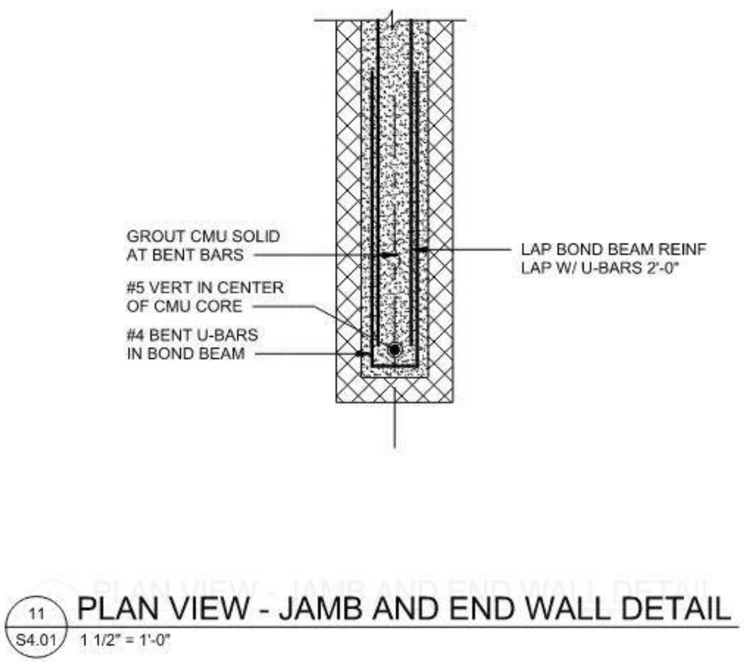


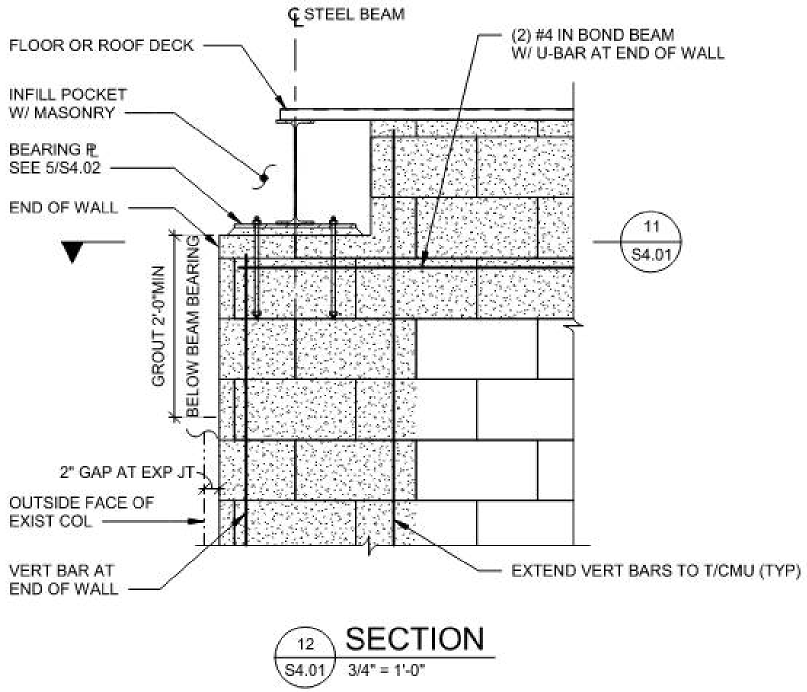
Figure CC-5.1-5. Distribution of concentrated loads

Beams Bearing in Walls

- Pay attention to bond beam layout
- Provide additional shear reinforcement at beams bearing at ends of walls.

Bearing Walls





Shear Walls

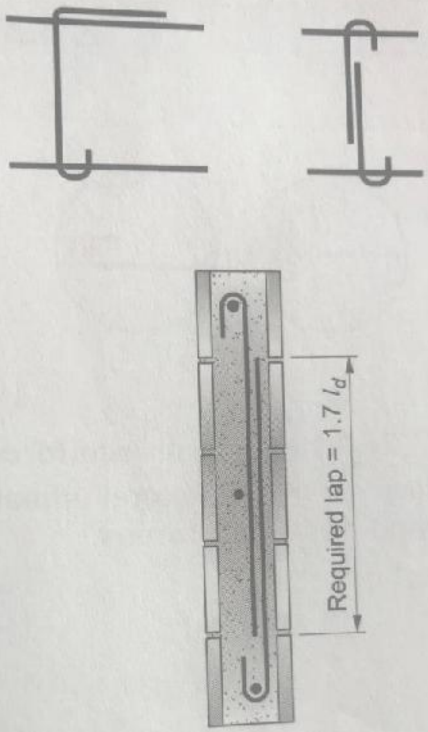


FIGURE 7.23 Anchorage details for shear reinforcement.

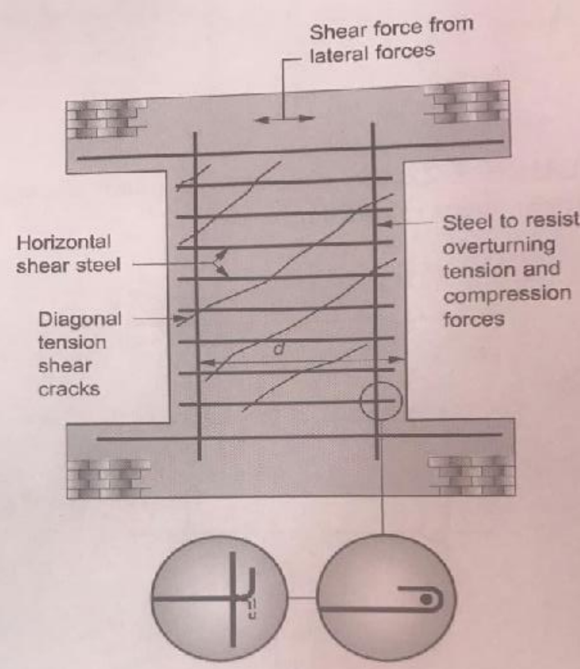


FIGURE 7.25 Shear wall reinforced with horizontal steel to resist lateral shear forces induced by wind or seismic forces.

6.1.6.1.1.3 Reinforcement spliced by noncontact lap splices shall not be spaced transversely farther apart than one-fifth the required length of lap nor more than 8 in. (203 mm). Noncontact splices are not permitted in AAC masonry.

6.1.7 *Shear reinforcement*

Shear reinforcement shall extend to a distance *d* from the extreme compression face and shall be carried as close to the compression and tension surfaces of the member as cover requirements and the proximity of other reinforcement permit. Shear reinforcement shall be anchored at both ends for its calculated stress.

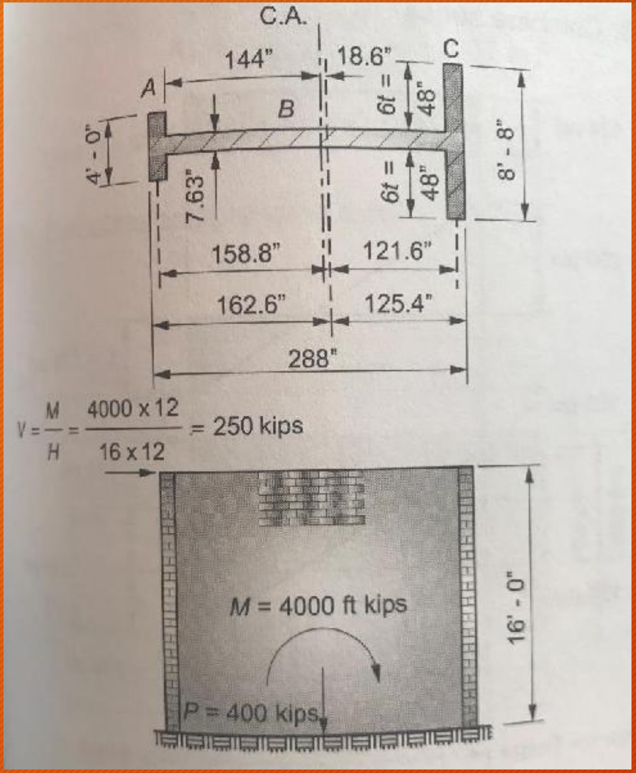
6.1.7.1 *Horizontal shear reinforcement*

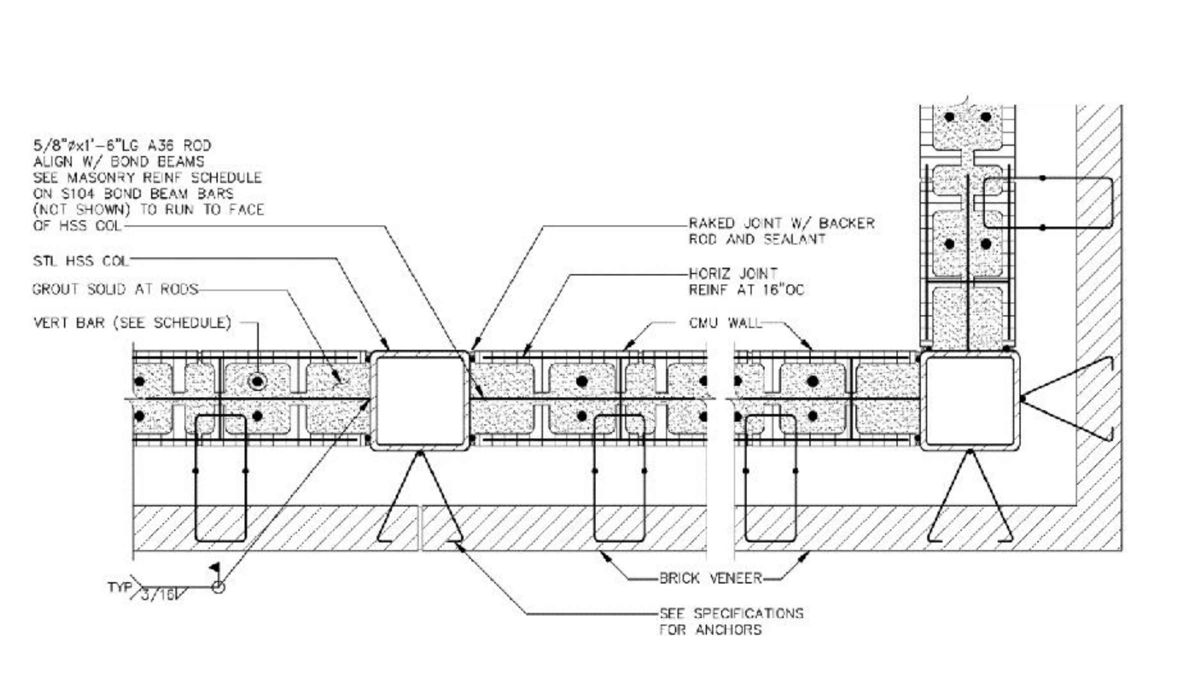
6.1.7.1.1 Except at wall intersections, the end of a horizontal reinforcing bar needed to satisfy shear strength requirements of Section 9.3.4.1.2 or Section 11.3.4.1.2 shall be bent around the edge vertical reinforcing bar with a 180-degree standard hook.

6.1.7.1.2 At wall intersections, horizontal reinforcing bars needed to satisfy shear strength requirements of Section 9.3.4.1.2 or 11.3.4.1.2 shall be bent around the edge vertical reinforcing bar with a 90-degree standard hook and shall extend horizontally into the intersecting wall a minimum distance at least equal to the development length.

- Shear reinforcement in the form of bars or wire joint reinforcement
- Shear reinforcement must be developed

Shear Walls


C.A.
144"
18.6"
C
A
B
6t = 48"
6t = 48"
4' - 0"
7.63"
8' - 8"
158.8"
121.6"
162.6"
125.4"
288"
V = M/H = (4000 x 12)/(16 x 12) = 250 kips
M = 4000 ft kips
P = 400 kips
16' - 0"


5/8"⌀x1'-6"LG A36 ROD
ALIGN W/ BOND BEAMS
SEE MASONRY REINF SCHEDULE
ON S104 BOND BEAM BARS
(NOT SHOWN) TO RUN TO FACE
OF HSS COL
STL HSS COL
GROUT SOLID AT RODS
VERT BAR (SEE SCHEDULE)
RAKED JOINT W/ BACKER
ROD AND SEALANT
HORIZ JOINT
REINF AT 16"OC
CMU WALL
TYP
3/16
BRICK VENEER
SEE SPECIFICATIONS
FOR ANCHORS

Shear Walls

5.1.1.2.5 The connection of intersecting walls shall conform to one of the following requirements:

(a) At least fifty percent of the masonry units at the interface shall interlock.

(b) Walls shall be anchored by steel connectors grouted into the wall and meeting the following requirements:

(1) Minimum size: 1/4 in. x 1 1/2 in. x 28 in. (6.4 mm x 38.1 mm x 711 mm) including 2-in. (50.8-mm) long, 90-degree bend at each end to form a U or Z shape.

(2) Maximum spacing: 48 in. (1219 mm).

(c) Intersecting reinforced bond beams shall be provided at a maximum spacing of 48 in. (1219 mm) on center. The area of reinforcement in each bond beam shall not be less than 0.1 in.^{2} per ft (211 mm^2/m) multiplied by the vertical spacing of the bond beams in feet (meters). Reinforcement shall be developed on each side of the intersection.

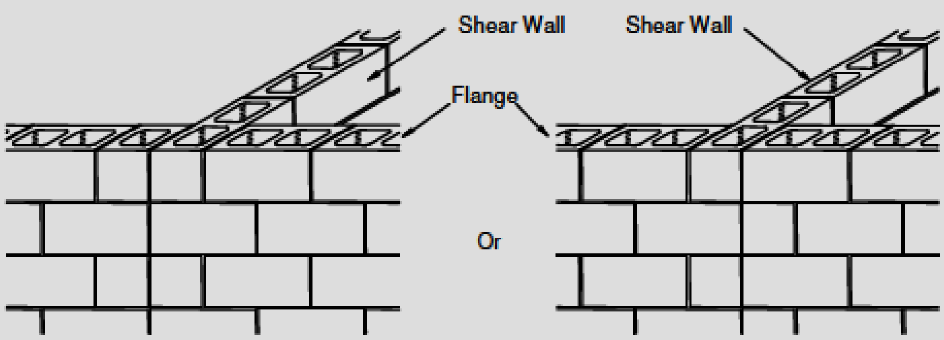


Figure CC-5.1-1 — Running bond lap at intersection

Shear Walls

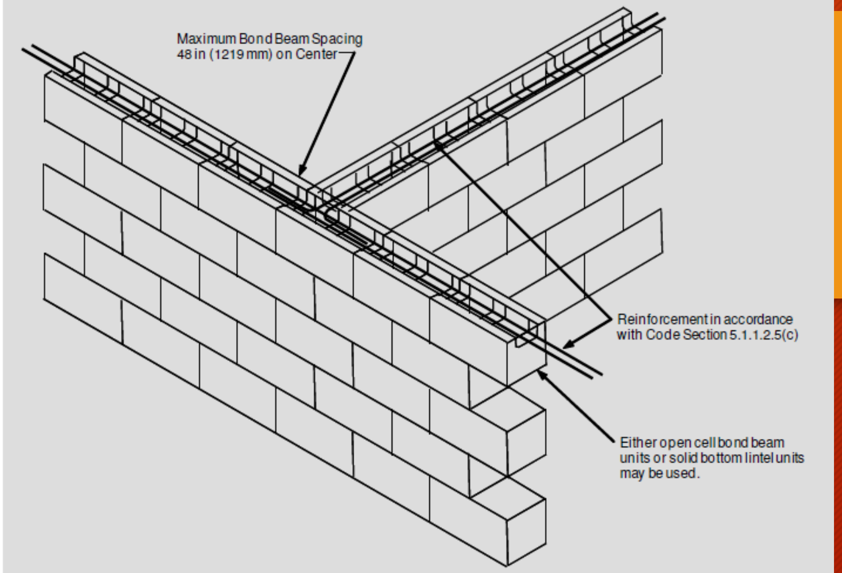


Figure CC-5.1-3 — Bond beam at wall intersection

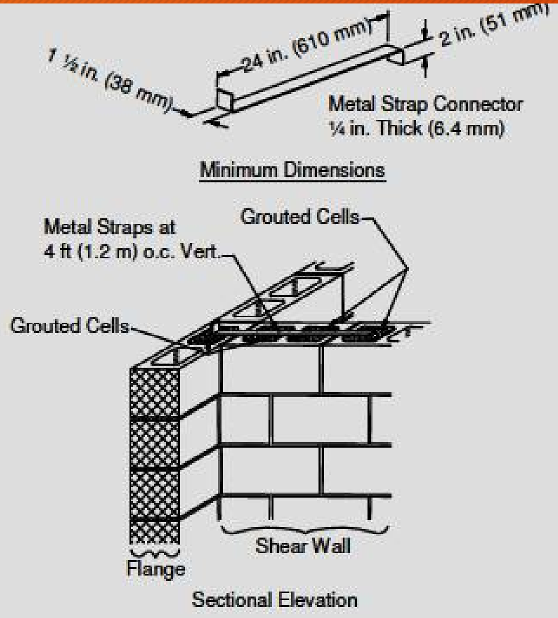
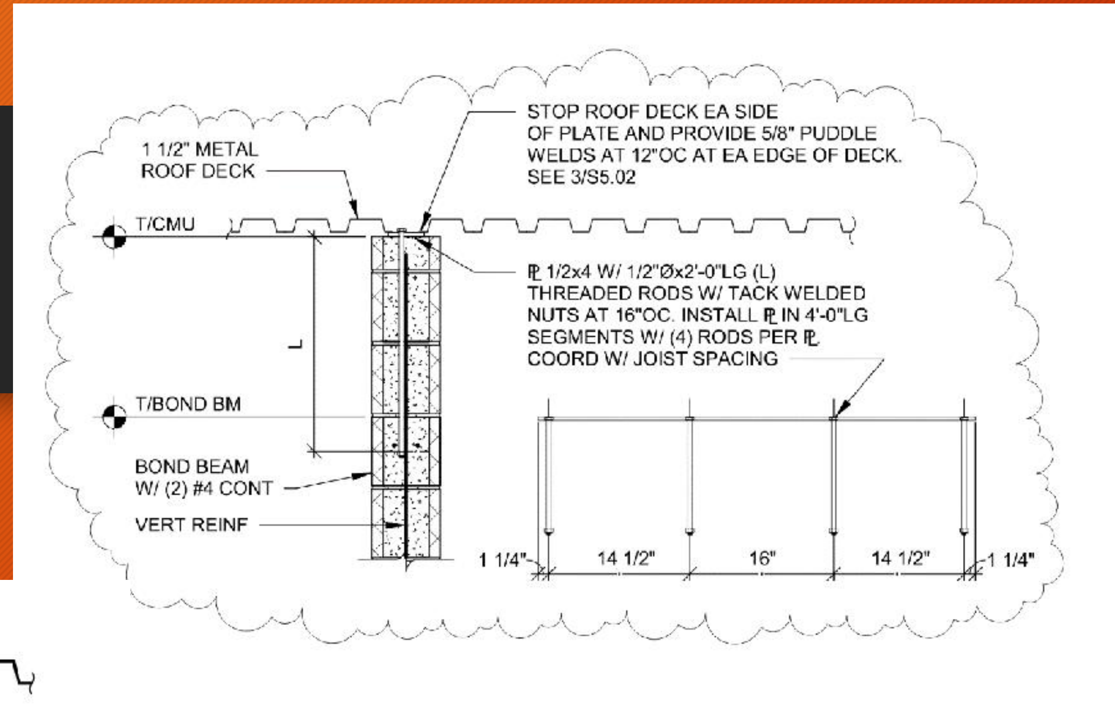
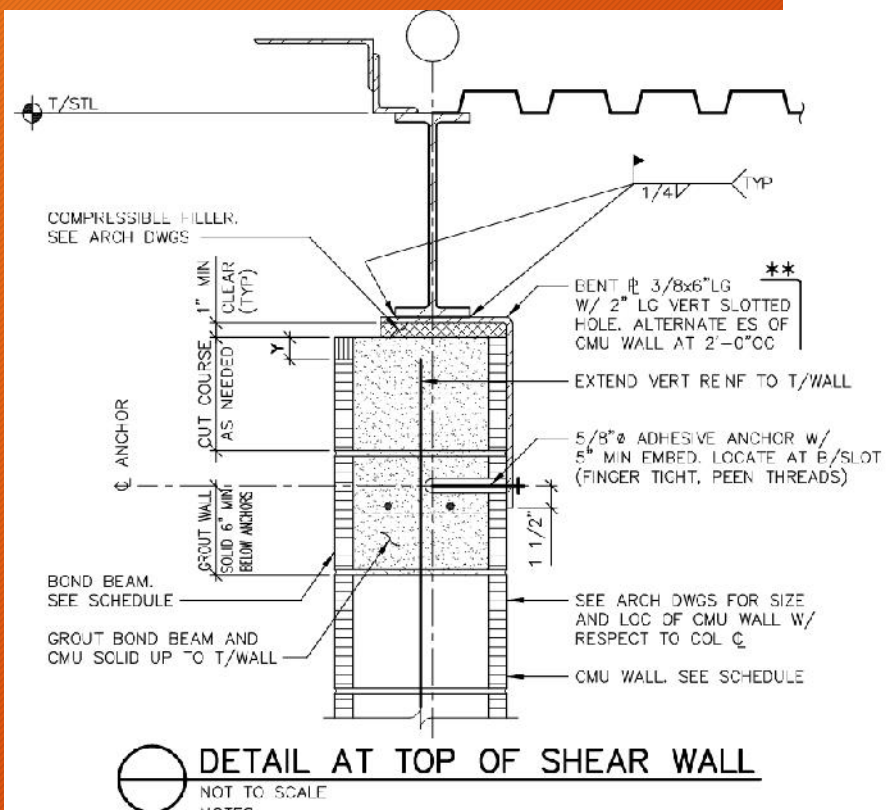


Figure CC-5.1-2 — Metal straps and grouting at wall intersections

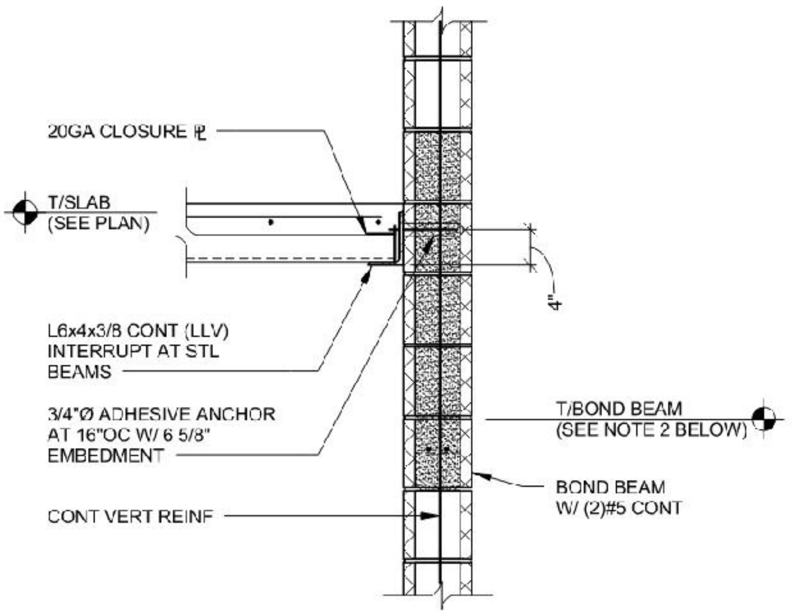
Diaphragms





Don’t forget about diaphragm chords and wind uplift!!!

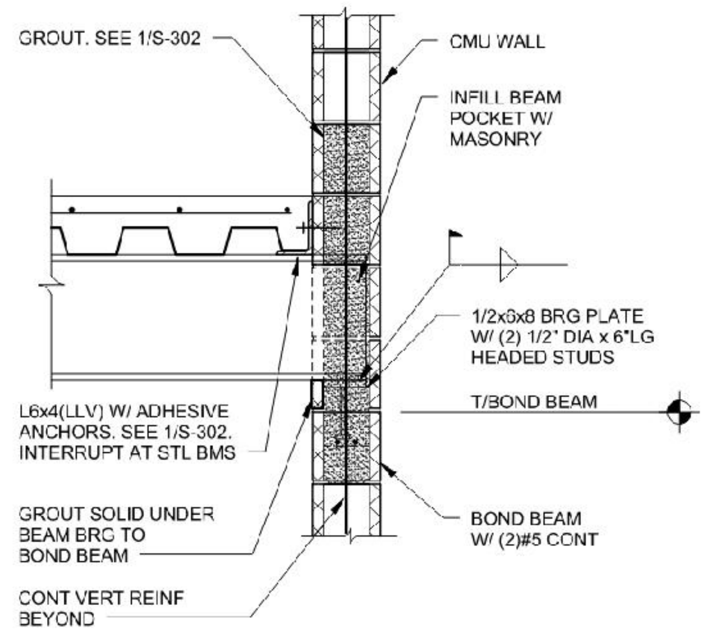
Diaphragms



NOTE:
BEAR DECK 2 1/2" MINIMUM ON SUPPORT.

1 / S-302 **DETAIL**
3/4" = 1'-0"

NOTES:
1. EXTEND GROUT TO INCLUDE FULL HEIGHT OF COURSE ABOVE SLAB.
2. T/BOND BEAM: (924'-10") SECOND FLOOR
   (935'-6") THIRD FLOOR
   (950'-10") ROOF
   (954'-6") PARAPET



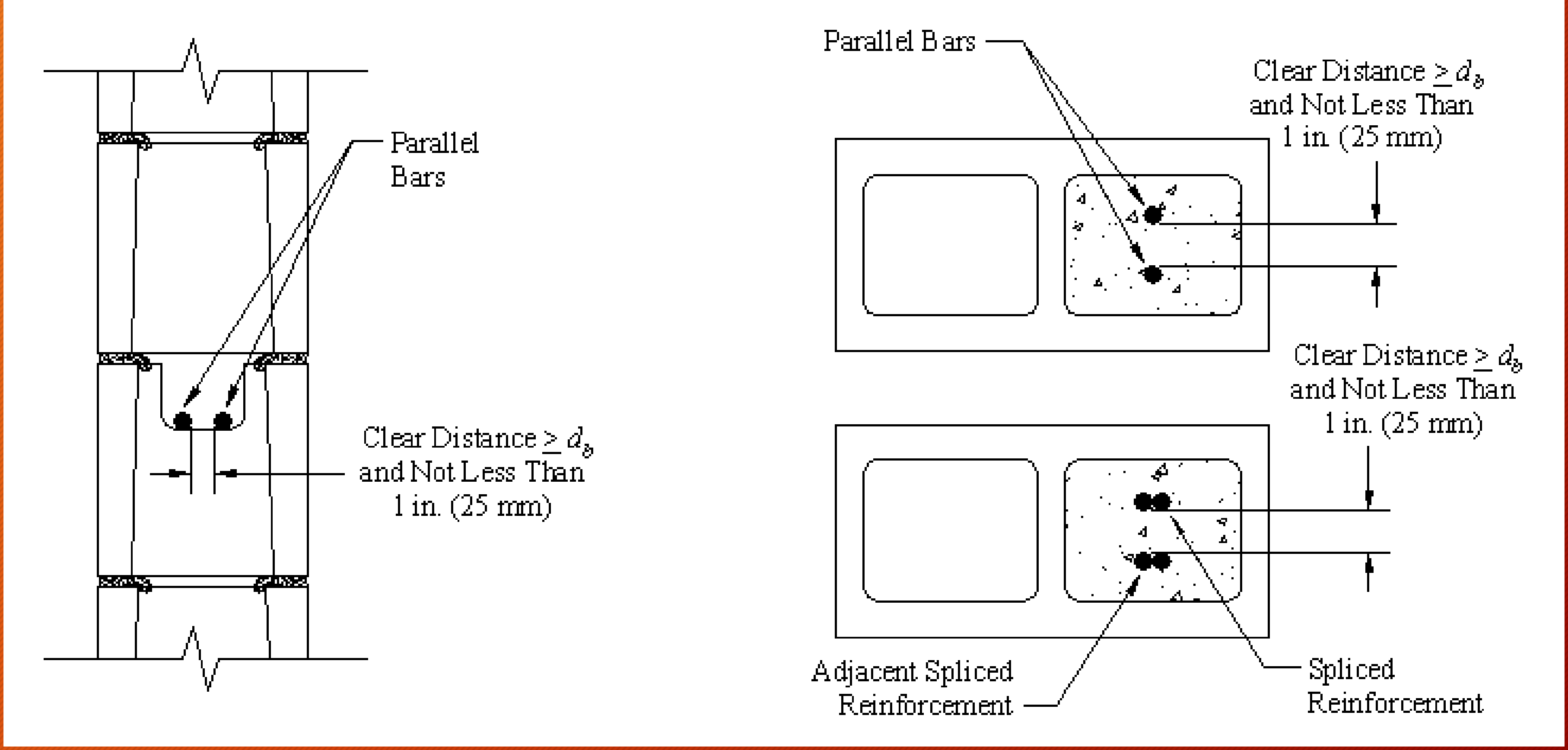
2 / S-302 **BEAM BEARING IN MASONRY WALL**
3/4" = 1'-0"

NOTE:
CONTRACTOR'S OPTION TO USE THREADED ROD WITH TACK WELDED NUT IN LIEU OF HEADED STUDS.

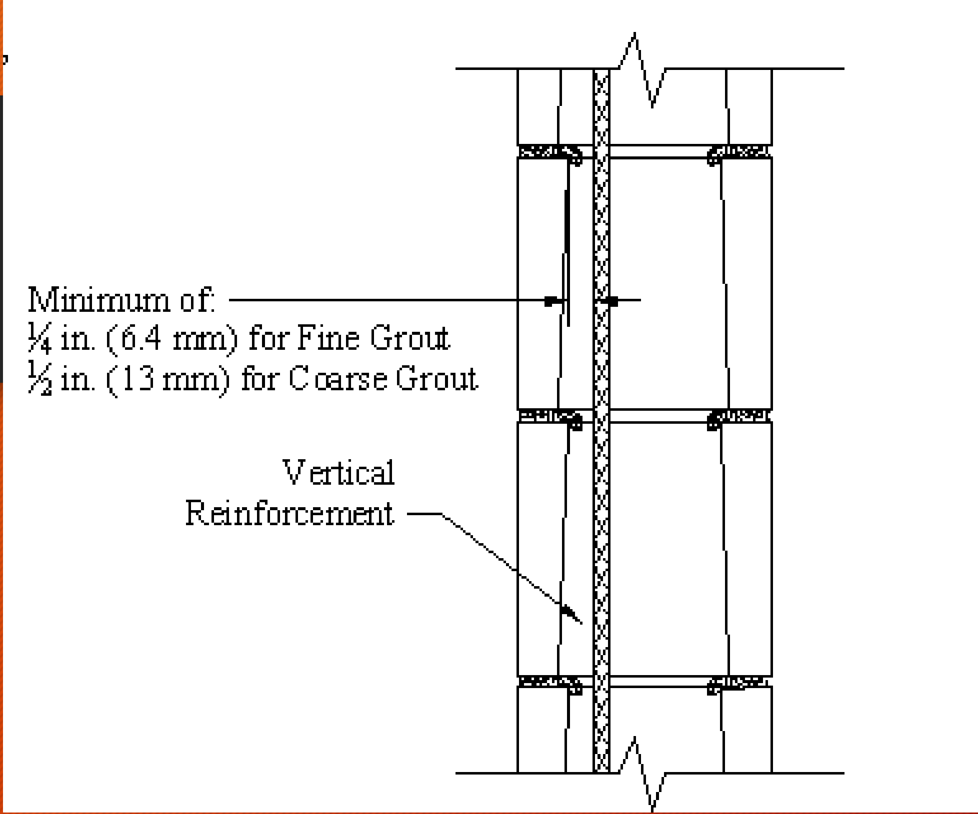
Reinforcement Placement

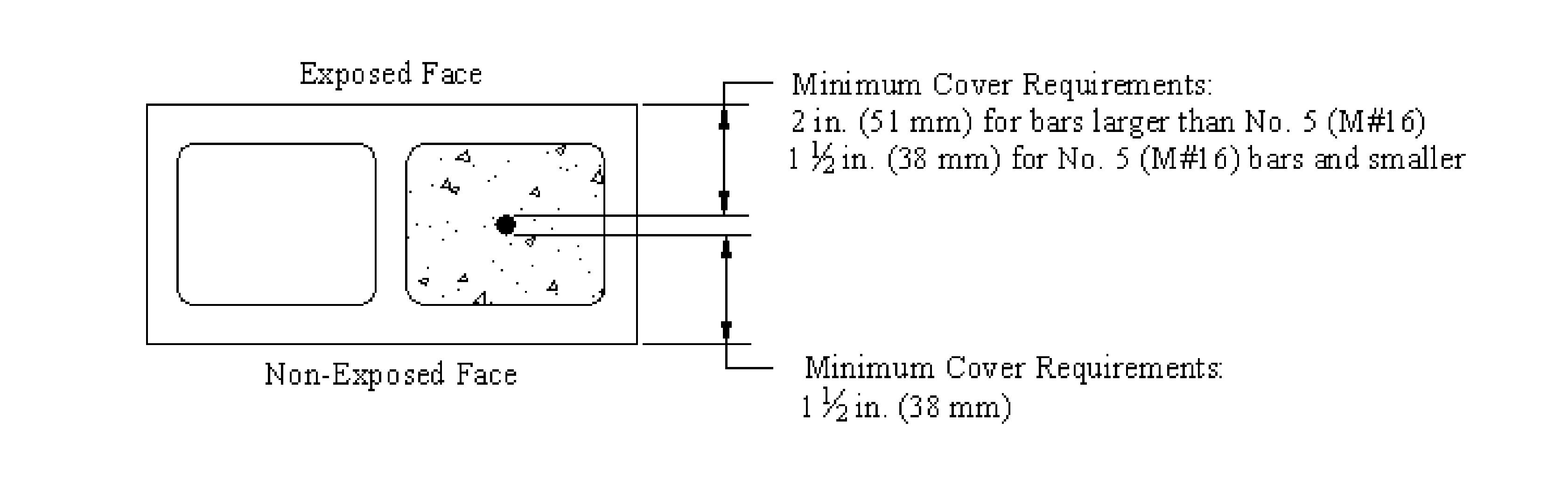
- Generally Periodic
- Size, grade, and location
- Laps lengths and splices

Reinforcement Placement



Reinforcement Placement

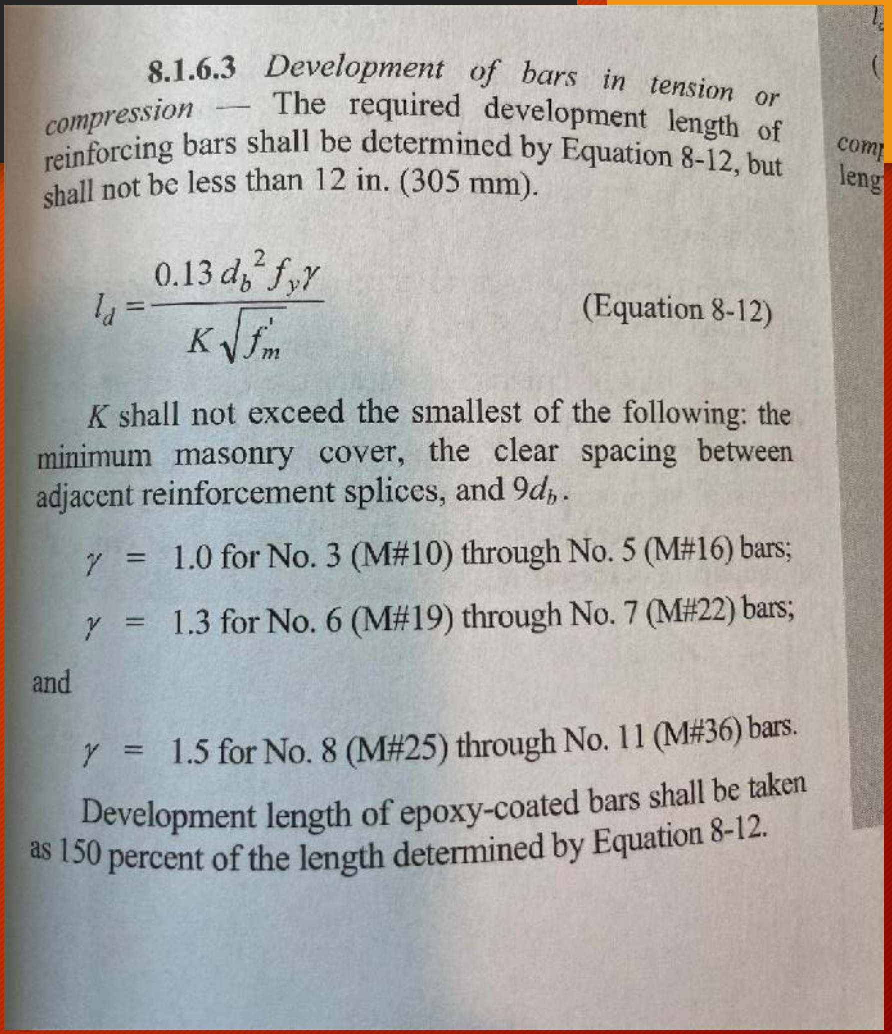




Bar Positioners - Best Practice

LAPS AND SPLICES

- Non-contact lap splices can be separated up to 1/5 the lap length but no more than 8”
- 40” lap = 8” separation
- 24” lap = ~ 4” separation
- IBC has different limits for lap lengths. 72 db max
- Lap splices become impractacle with larger bar sizes
- Strength design generally yields lower lap lengths



8.1.6.3 *Development of bars in tension or compression* — The required development length of reinforcing bars shall be determined by Equation 8-12, but shall not be less than 12 in. (305 mm).

$$l_d = \frac{0.13\, d_b^{\,2} f_y \gamma}{K \sqrt{f'_m}} \qquad \text{(Equation 8-12)}$$

K shall not exceed the smallest of the following: the minimum masonry cover, the clear spacing between adjacent reinforcement splices, and $9d_b$.

γ = 1.0 for No. 3 (M#10) through No. 5 (M#16) bars;

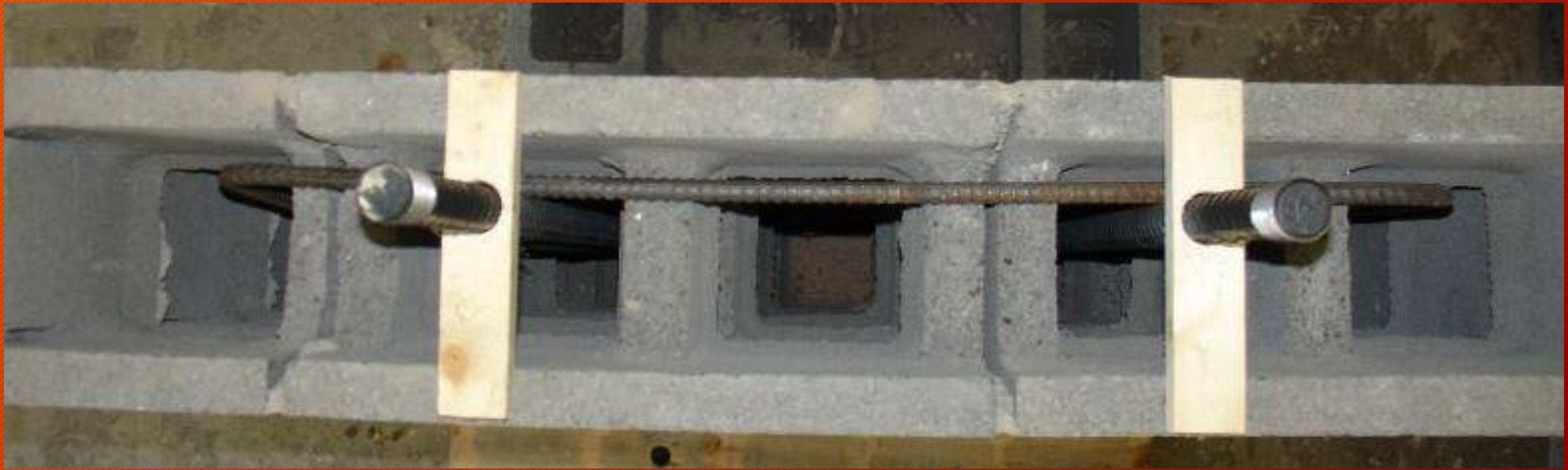
γ = 1.3 for No. 6 (M#19) through No. 7 (M#22) bars;

and

γ = 1.5 for No. 8 (M#25) through No. 11 (M#36) bars.

Development length of epoxy-coated bars shall be taken as 150 percent of the length determined by Equation 8-12.

Splice Couplers/Welding



Considerations

- Attempt to use #6 or smaller bars if possible and space grouted cells more closely. (Limited to 6t for seismic)
- Use rebar couplers for larger bar sizes

GROUTING

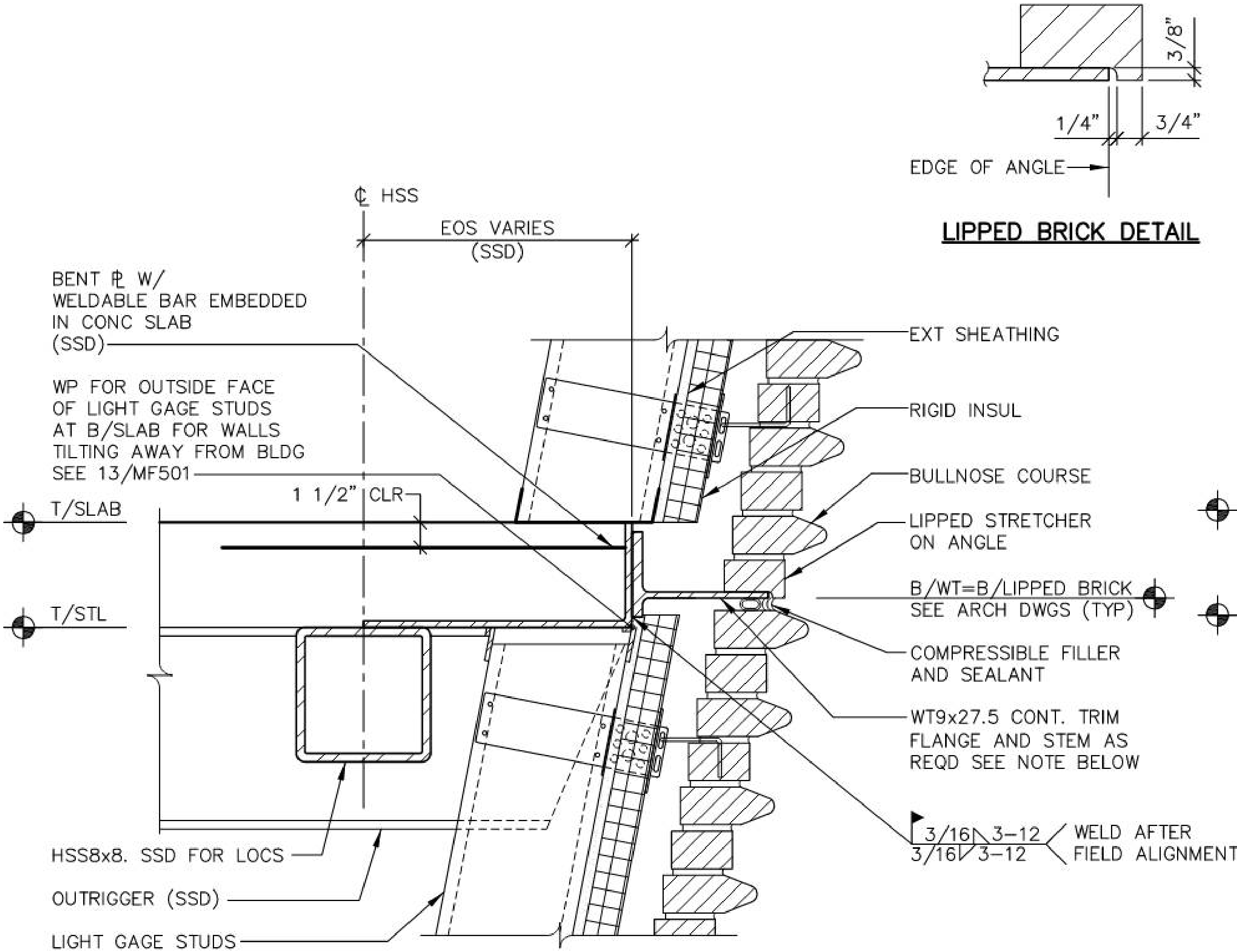
- The code has requirements for fine vs coarse grout based on masonry size and pour height
- Don’t allow wet-sticking of reinforcement into grouted cells
- Grout needs to be consolidated around reinforcement after placement.
- High lift grouting requires cleanouts at the bottom of grouted cells

Wall Joints

- Review with Architect early in the project. Do not leave it up to the Contractor
- Empirical Method of joint spacing is common (NCMA – TEK)
- Rules of thumb (joint spacing):
  - Unit height 8” - l/h = 1.5 or 25 feet maximum
  - Unit height 4” – l/h = 1.5 or 20 feet maximum
- Review minimum joint reinforcement:
  - 0.025 in^2/ft for 8” units, 0.034 in^2/ft for 4” units

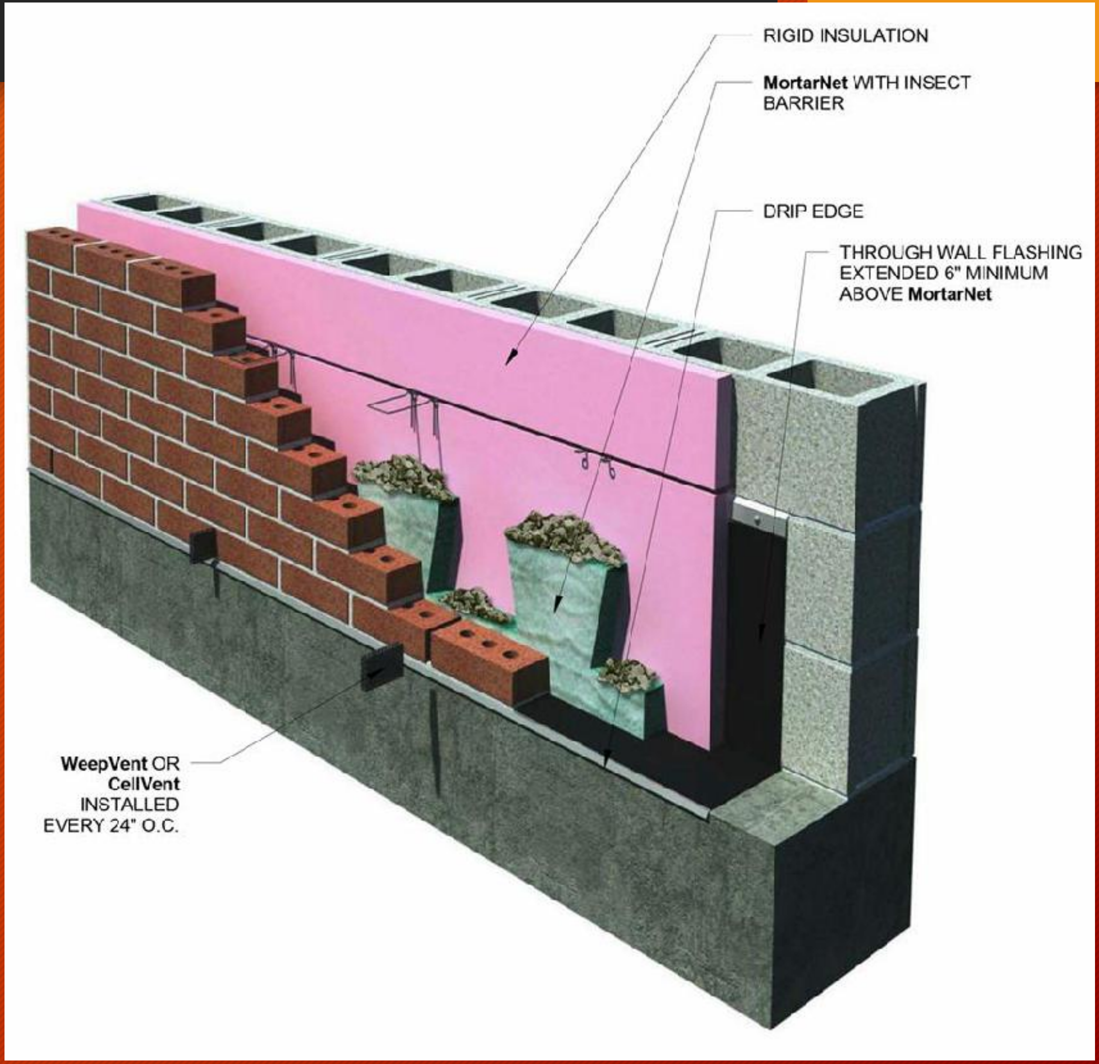
Other Considerations for Joints

- Openings, corners, returns, create discontinuities in the wall system that can lead to cracking.
- Clay masonry veneer will expand and CMU backup will contract. Keep this in mind with jointing. You may need more veneer joints than backup joints.
- Joints are not just vertical. Carefully review detailing at horizontal relief angles for anticipated vertical movement in services in combination with brick growth.


LIPPED BRICK DETAIL
3/8"
1/4"
3/4"
EDGE OF ANGLE
℄ HSS
EOS VARIES
(SSD)
BENT ℄ W/
WELDABLE BAR EMBEDDED
IN CONC SLAB
(SSD)
WP FOR OUTSIDE FACE
OF LIGHT GAGE STUDS
AT B/SLAB FOR WALLS
TILTING AWAY FROM BLDG
SEE 13/MF501
T/SLAB
1 1/2" CLR
T/STL
EXT SHEATHING
RIGID INSUL
BULLNOSE COURSE
LIPPED STRETCHER
ON ANGLE
B/WT=B/LIPPED BRICK
SEE ARCH DWGS (TYP)
COMPRESSIBLE FILLER
AND SEALANT
WT9x27.5 CONT. TRIM
FLANGE AND STEM AS
REQD SEE NOTE BELOW
3/16 3-12
3/16 3-12
WELD AFTER
FIELD ALIGNMENT
HSS8x8. SSD FOR LOCS
OUTRIGGER (SSD)
LIGHT GAGE STUDS

Cavity Wall Systems

- Consider veneer/cladding anchoring system
- Pay attention to cavity drainage and venting…it's OK to point out missing components to the Architect



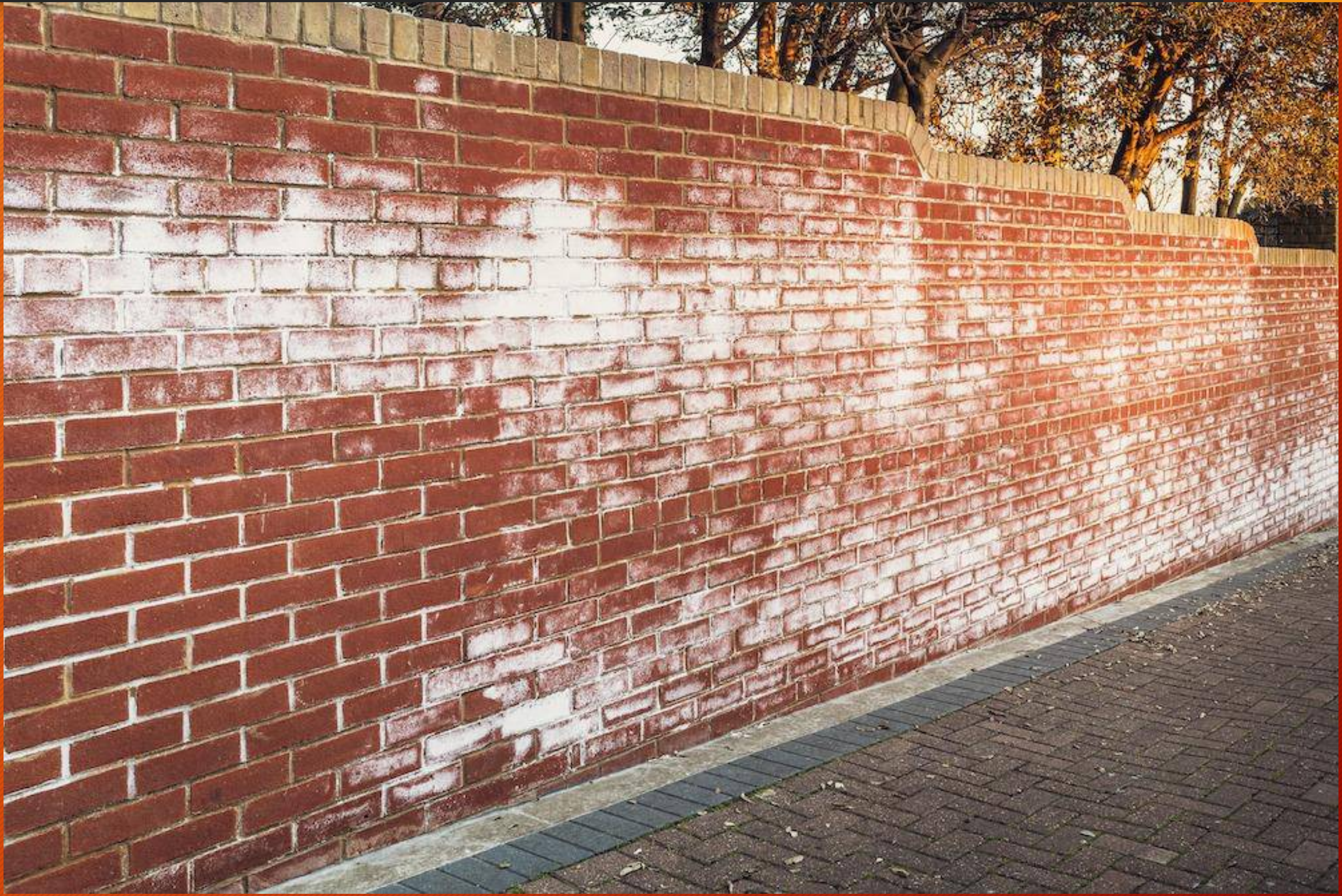
Cavity Wall Protection

- Do not use rope wicks or tubes to vent cavities...use weep vents.

Cavity Wall Protection

- Cover tops of walls at the end of each work day to prevent excess moisture from entering the wall system

Efflorescence



Single Wythe Masonry Walls

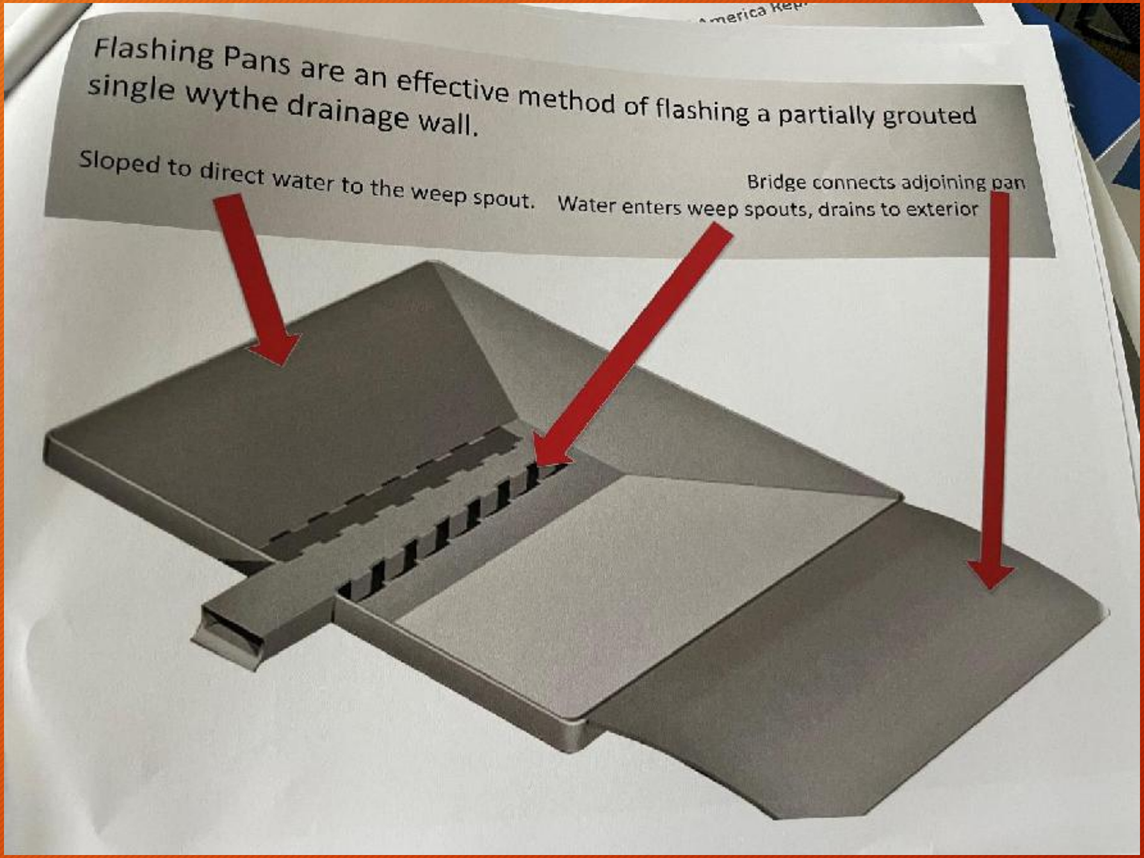
- Must consider insulation and water resistance
- New systems have been developed to reduce thermal bridging and create a waterproof system
- If specifying integral waterproofing admixture for CMU, you MUST specify it in the mortar.
- Specify a post-applied spray-on breathable water repellant on exterior surface. The post-application will cover the units and the mortar and preserve the appearance.

Construction Implications

H-Block – better suited for solid grouted applications.

A-Block – better option for partial grouted applications.

Single Wythe Drainage



Insulation

QUESTIONS